

Docket #71131

BREATHING EQUIPMENT WITH A CIRCUIT FOR BREATHING GAS

FIELD OF THE INVENTION

[0001] The present invention pertains to a respirator with a circuit for breathing gas with a flat calcium hydroxide absorber cooled by an evaporating agent.

BACKGROUND OF THE INVENTION

5 **[0002]** Respiration is performed in a circuit in breathing equipment, especially in gas masks, to reduce the weight and to prolong the service life, and only the amount of oxygen having been consumed is added from a pressurized gas reserve. To prevent the carbon dioxide (CO₂) breathed out from accumulating in the circuit to nonphysiological levels, an absorber with an absorbent, which removes the CO₂ from the breathing circuit, is present in the circuit. Prior-art
10 absorbents consist of one or more alkali hydroxides and contain or consist especially of calcium

hydroxide. Heat and moisture are generated during the chemical reaction taking place between the CO₂ and the absorbent, and this may lead to an increase in the breathing gas temperature and to discomfort for the person respirated through the breathing equipment. Thus, temperatures that were up to 15°C higher than the particular ambient temperature were measured after the absorber, and the breathing gas is saturated with moisture. It was therefore proposed that gas masks that are used for a prolonged period of time of several hours be equipped with a breathing gas cooler.

[0003] The use of paraffin or a salt as a coolant for such breathing equipment is disclosed in DE 879 651 B; the evaporation temperature or the melting point is between 40°C and 180°C here, and the alkali cartridge is surrounded by the coolant.

[0004] As an addition to DE 879 651 B, DE 916 384 B shows as a characterizing feature that the cooling jacket is formed from at least one layer of corrugated board provided especially with continuous longitudinal openings, which are covered by smooth board layers on both sides, so that channels are formed, which facilitate the absorption of cooling liquid by the jacket.

SUMMARY OF THE INVENTION

[0005] The object of the present invention is to provide breathing equipment with a circuit for breathing gas with improved cooling for the breathing gas.

[0006] According to the invention, breathing equipment is provided with a circuit for breathing gas and with a flat calcium hydroxide absorber cooled by an evaporating agent. The

equipment admits a gas volume flow of at least 60 L per minute to the outer surface of the calcium hydroxide absorber receiving the evaporating agent. The evaporating agent is delivered to the outer surface of the calcium hydroxide absorber by means of admitted pressure from a evaporating agent reservoir via at least one connection line.

5 **[0007]** An essential advantage of the present invention is the flat design of the especially parallelepipedic calcium hydroxide absorber with a depth of up to 70 mm, on average, so that the heat conduction paths from the calcium hydroxide pellets with poor thermal conductivity to the outer surface of the calcium hydroxide absorber is as short as possible. This is absolutely necessary because the heat output to be removed during the absorption of CO₂ in the calcium
10 hydroxide is not transferred efficiently to the outer surface of the calcium hydroxide absorber: In the case of a hypothetical period of use of four hours and a respiratory minute volume of 30 L per minute of the user of the breathing equipment, a thermal energy of about 750 kJ is generated in about 3 L of calcium hydroxide, and this amount of thermal energy must be removed according to the present invention in order to achieve the cooling of the calcium hydroxide absorber.

15 **[0008]** Instead of a flat, parallelepipedic calcium hydroxide absorber, it is also possible to use a plurality of absorbers arranged in parallel in a gas flow connection or absorbers provided with at least one continuous ventilation slot. It is essential that the calcium hydroxide in the calcium hydroxide absorber have the shortest possible heat conduction paths to the outer surface of the absorber.

20 **[0009]** A hydrophilic material, which is moistened with the evaporating agent and makes

possible good evaporation and cooling associated therewith, is applied or clamped on the outer surface of the calcium hydroxide absorber. At the same time, this hydrophilic material has the best heat conduction possible so that no additional thermal resistance will build up for the heat conduction from the calcium hydroxide. Cotton and silk have proved to be especially suitable materials for the outer surface of the calcium hydroxide absorber for absorbing the evaporating agent.

[0010] The use of a gas delivery means with a gas volume flow of at least 60 *L* per minute proved to be absolutely necessary in order to generate the amounts of convection air necessary for the heat transport from the calcium hydroxide absorber. An electrically driven positive displacement blower designed as a fan is used in the simplest case, which delivers a gas volume flow of preferably 150 *L* to 250 *L* per minute as uniformly as possible along the entire outer surface of the calcium hydroxide absorber in order to achieve the evaporation of the evaporating agent, especially water, an aqueous solution or a mixture with water, which cools the environment, as well as to make possible the convective cooling, both of which are necessary to remove the thermal energy generated in the calcium hydroxide absorber containing, e.g., 3 *L* of calcium hydroxide.

[0011] Corresponding measurements confirmed these results when the user of the breathing equipment generates a usual respiratory minute volume of 30 *L* per minute and a corresponding amount of CO₂, which is reacted in the calcium hydroxide absorber with an associated release of thermal energy.

[0012] The evaporating agent is distributed on the outer surface as uniformly as possible for the good evaporation of the evaporating agent over the entire outer surface of the calcium hydroxide absorber. The evaporating agent reservoir is provided for this purpose with a hose type distributor in order to distribute the evaporating agent, e.g., on all four sides of a parallelepipedic calcium hydroxide absorber by means of the corresponding connection lines.

[0013] Each of the outlets of the connection lines ending on the outer surface of the calcium hydroxide absorber is preferably provided with a porous or fibrous material such as cellulose acetate, so that an equal pressure resistance and the most uniform moistening possible of the outer surface of the calcium hydroxide absorber are guaranteed.

[0014] It is necessary according to the present invention to admit pressure to the evaporating agent in the connection lines for the uniform distribution of the evaporating agent on the outer surface of the calcium hydroxide absorber. Pressure is admitted for this purpose, in particular, to the evaporating agent reservoir by means of a pretensioned spring, or pressure is generated in the connection lines by means of an electrically or mechanically driven pump, especially by means of a hose pump. If the breathing equipment has a breathing bag, which is in gas flow connection with the circulation and can be reversibly inflated by the respiratory flow, the breathing bag is connected to the pump either purely mechanically or electromechanically in a variant of the present invention such that the movement of the breathing bag is utilized as the drive for the pump. For example, a slight rotation of a hose pump may thus occur during each

expansion or resetting of the breathing bag via a lever and locking teeth or a roller clutch. The evaporating surface corresponding to the outer surface of the calcium hydroxide absorber is then flooded in proportion to the breathing stroke and the respiration rate. The pump is switched on automatically at the start of the breathing equipment and stops automatically when the user of the breathing equipment detaches his breathing tubes from the breathing equipment. Continued pumping and the running out of the evaporating agent are thus prevented from occurring.

[0015] Besides a pump or spring mechanism alternate means may be used to admit pressure to the evaporating agent in the connection lines for the uniform distribution of the evaporating agent on the outer surface of the calcium hydroxide absorber. One advantageous approach is to exert pressure on the evaporating agent reservoir. This may be done by providing a pressurized gas contained in a separate gas reservoir or by preferably using the breathing gas pressure of the breathing gas reservoir which is a standard component of most breathing equipment used for personal protection in mining operations, fire rescue devices and similar devices.

[0016] The use of pressurized fluid to exert pressure on the evaporating agent may be by use of a vessel, tank, cartridge or other structure such as a movable pump piston for the separation of media, pressure applying fluid and the liquid evaporation agent, as well as providing pressure transmission between the media. The separation and pressure transmission feature may be provided via a flexible tank within a vessel, tank, cartridge or other structure or via a flexible membrane, diaphragm, bellows or bubble structure within a vessel, tank, cartridge or other

structure.

[0017] An exemplary embodiment of the present invention will be explained below by means of the schematic figures.

[0018] The various features of novelty which characterize the invention are pointed out with particularity in the claims annexed to and forming a part of this disclosure. For a better understanding of the invention, its operating advantages and specific objects attained by its uses, reference is made to the accompanying drawings and descriptive matter in which preferred embodiments of the invention are illustrated.

BRIEF DESCRIPTION OF THE DRAWINGS

[0019] Figure 1 is a partially schematic sectional view through a breathing device or the breathing equipment showing the most important components according to a first embodiment of the invention showing two alternative evaporating agent delivery means;

[0020] Figure 2 is a partially schematic sectional view through a breathing device or the breathing equipment showing the most important components according to a second embodiment of the invention;

[0021] Figure 3 is a partially schematic sectional view through a breathing device or the breathing equipment showing the most important components according to a third embodiment of

the invention;

[0022] Figure 4A is a schematic view showing a media separation and pressure transmission device having a piston;

[0023] Figure 4B is a schematic view showing another media separation and pressure transmission device having a piston;

[0024] Figure 4C is a schematic view showing another media separation and pressure transmission device having a piston;

[0025] Figure 5A is a schematic view showing a media separation and pressure transmission device having plural pistons and cylinders;

[0026] Figure 5B is a schematic view showing a media separation and pressure transmission device having a bellows arrangement for the high pressure fluid and with a piston and cylinder for the evaporating agent;

[0027] Figure 5C is a schematic view showing a media separation and pressure transmission device having a bellows arrangement for the evaporating agent with a piston and cylinder for the high pressure fluid;

[0028] Figure 6A is a schematic view showing a media separation and pressure

transmission device having a flexible agent reservoir or bellows in a pressure tank;

[0029] Figure 6B is a schematic view showing a media separation and pressure transmission device having a flexible bubble or bellows receiving the high pressure fluid with the evaporation agent in the tank; and

5 [0030] Figure 6C is a schematic view showing a media separation and pressure transmission device with a flexible membrane or bellows in the pressure tank and the high pressure fluid on one side and with the evaporation agent on the other side.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

[0031] Referring to the drawings in particular, Figures 1, 2 and 3 show three embodiments
10 of breathing equipment with a circuit for breathing gas according to the invention. In each of these embodiments a calcium hydroxide absorber 1 is located in a breathing device housing or breathing equipment housing 9. The expired air of the user of the breathing equipment is released via tubes and the inlet 2 into the calcium hydroxide absorber 1. The user of the breathing equipment again breathes from the breathing equipment via tubes via the outlet 3. The user
15 breathes in directly from the breathing bag 7, which is connected to the calcium hydroxide absorber 1 via a gas connection line 6. The circuit for breathing gas is now closed. A first opening 4 in the breathing equipment housing 9 is arranged in each exemplary embodiment on the side, i.e., on the right in each figure, on which side an electrically driven fan is also arranged as a

gas delivery means 5, which draws in air from the environment. The air is removed on the opposite side through the second opening 13 shown on the left in the figure in the direction of the arrow. The air now sweeps over the outer surface 14 of the calcium hydroxide absorber 1 and removes the evaporated evaporating agent, especially water, with the air being delivered into the environment.

[0032] The outer surface 14 of the calcium hydroxide absorber 1 is covered with a hydrophilic web of fabric, e.g., one made of cotton, which is uniformly wetted and moistened with evaporating agent from the evaporating agent reservoir 10 via the at least one connection line outlet 15 of the at least one connection line 12.

[0033] According to the embodiment of Figure 1, the supply with evaporating agent 30 is ensured by an evaporating agent delivery means in the form of a pump 11, which is driven either mechanically or electrically and is designed especially as a hose pump. In a variant of the embodiment of Figure 1 of the present invention, the evaporating agent delivery means comprises a spring 16 acting on a flexible portion of the evaporating agent reservoir 10.

[0034] According to each of the embodiments the evaporating agent reservoir 10 is dimensioned such that it contains a sufficient amount of evaporating agent for the duration of the mission of the user of the breathing equipment or of the breathing equipment. In the case of water, 300 mL to 400 mL are sufficient for a service life of 4 hours. A high-pressure oxygen cylinder 8 with a pressure regulator may be provided to continuously replenish the oxygen

consumed in the circulation. The cylinder 8 is located in the breathing equipment housing 9.

[0035] In another variant of the embodiment of Figure 1 of the present invention, the pump 11 is connected to the breathing bag 7 via a mechanical or electromechanical connection in order to adapt the cooling and consequently the amount of evaporating agent released from the evaporating agent reservoir 10 to the respiratory minute volume of the user of the breathing equipment, to start and also to end the evaporative cooling by the delivery of the evaporating agent to the outer surface 14.

[0036] The embodiment of Figure 2 is similar to the embodiment of Figure 1 except the evaporating agent delivery means is a media separation and pressure transmission means or device 20, employed to supply the evaporating agent. The media separation and pressure transmission device 20 uses high pressure fluid as the source of pressure to supply the evaporating agent. Various embodiments of media separation and pressure transmission device 20 are described below with reference to Figures 4A to 6C. In the embodiment of Figure 2, the breathing bag 7 is the source of the high pressure fluid acting to apply pressure on the evaporating agent via the media separation and pressure transmission device 20.

[0037] The embodiment of Figure 3 is similar to the embodiment of Figure 1 except the a media separation and pressure transmission device 20 is employed to supply the evaporating agent. The media separation and pressure transmission device 20 uses high pressure fluid as the source of pressure to supply the evaporating agent. Various embodiments of media separation

and pressure transmission device 20 are described below with reference to Figures 4A to 6C. In the embodiment of Figure 3, pressurized gas contained in a separate reservoir 22 is the source of the high pressure fluid acting to apply pressure on the evaporating agent via the media separation and pressure transmission device 20. The separate reservoir 22 may alternatively be connected to the high-pressure oxygen cylinder 8 via a connection line 24 or instead of a separate reservoir 22 or reservoir 22 acting as an intermediary, the high-pressure oxygen cylinder 8 may be the source of the high pressure fluid acting to apply pressure on the evaporating agent via the media separation and pressure transmission device 20.

[0038] Figure 4A schematically shows the media separation and pressure transmission device 20 having a piston 26 movable in a tank 28. The tank 28 is in fluid communication with the agent 30 and the high pressure fluid or pressurized gas 32. By admitting the pressurized gas 32 into the tank 28, a force is applied on the piston 26 (that is higher than the force applied on the other side of the piston by the evaporating agent) resulting in the supply of evaporating agent 30 to the outer surface 14 of the calcium hydroxide absorber 1.

[0039] Figure 4B schematically shows the media separation and pressure transmission device 20 having a piston 26 movable in a cartridge 34 that is in a tank 28. The cartridge 34 is in fluid communication with the agent 30 on one side of the piston 26. The other side of the piston 26 is in fluid communication with the high pressure fluid or pressurized gas 32 in the interior of the tank 28. By admitting the pressurized gas 32 into the tank 28, a force is applied on the piston 26 resulting in the supply of evaporating agent 30 to the outer surface 14 of the calcium

hydroxide absorber 1.

[0040] Figure 4C schematically shows the media separation and pressure transmission device 20 having a piston 26 movable in a cartridge 34 that is in a tank 28. The cartridge 34 is in fluid communication with the high pressure fluid or pressurized gas 32 on one side of the piston 26. The other side of the piston 26 is in fluid communication with the agent 30 in the interior of the tank 28. By admitting the pressurized gas 32 into the cartridge 34, a force is applied on the piston 26 resulting in the supply of evaporating agent 30 to the outer surface 14 of the calcium hydroxide absorber 1.

[0041] Figure 5A schematically shows the media separation and pressure transmission device 20 having a first piston 26 and a cylinder 36 cooperating with a second piston 40 in a cylinder 42 via a connection element 38. The cylinder 36 is in fluid communication with the high pressure fluid or pressurized gas 32 on a pressure side of the piston 26. The other piston 40 is in fluid communication with the agent 30 in the interior of the cylinder 42. By admitting the pressurized gas 32 into the cartridge 34, a force is applied on the piston 26 and transmitted to piston 40 via connecting element 38, resulting in the supply of evaporating agent 30 to the outer surface 14 of the calcium hydroxide absorber 1.

[0042] Figure 5B schematically shows the media separation and pressure transmission device 20 having a bellows 44 cooperating with a piston 40 in a cylinder 42 via a connection element 38. The bellows 44 is in fluid communication with the high pressure fluid or pressurized

gas 32. The piston 40 is in fluid communication with the agent 30 in the interior of the cylinder 42. By admitting the pressurized gas 32 into the bellows 44, a force is applied to expand the bellows 44 and the expansion force acts on piston 40 via connecting element 38, resulting in the supply of evaporating agent 30 to the outer surface 14 of the calcium hydroxide absorber 1.

5 **[0043]** Figure 5C schematically shows the media separation and pressure transmission device 20 having a piston 26 and a cylinder 36 cooperating with a bellows 46 via a connection element 38. The cylinder 36 is in fluid communication with the high pressure fluid or pressurized gas 32 on a pressure side of the piston 26. The bellows 46 is in fluid communication with the agent 30 in the interior of the bellows 46. By admitting the pressurized gas 32 into the bellows 44, a force is applied to the piston 26, which acts on piston bellows 46 via connecting element 38 to contract the bellows 46 resulting in the supply of evaporating agent 30 to the outer surface 14 of the calcium hydroxide absorber 1.

15 **[0044]** Figure 6A schematically shows the media separation and pressure transmission device 20 having a flexible agent reservoir or bellows (or bubble membrane) 50 in a pressure tank 52. By admitting the pressurized gas 32 into the tank 52, a force acts on bellows 50 to contract the bellows 50 resulting in the supply of evaporating agent 30 to the outer surface 14 of the calcium hydroxide absorber 1.

[0045] Figure 6B schematically shows the media separation and pressure transmission device 20 having a flexible agent reservoir or bellows (or bubble membrane) 50 in a pressure tank

52. By admitting the pressurized gas 32 into the bellows 50, a force acts on bellows 50 to expand the bellows 50 resulting in the supply of evaporating agent 30 to the outer surface 14 of the calcium hydroxide absorber 1.

[0046] Figure 6C schematically shows the media separation and pressure transmission device 20 having a diaphragm membrane 54 in a pressure tank 52. By admitting the pressurized gas 32 into the tank 52, a force acts on diaphragm membrane 54 resulting in the supply of evaporating agent 30 to the outer surface 14 of the calcium hydroxide absorber 1.

[0047] While specific embodiments of the invention have been shown and described in detail to illustrate the application of the principles of the invention, it will be understood that the invention may be embodied otherwise without departing from such principles.